Thoracoscopic sympathetic clipping for hyperhidrosis: Long-term results and reversibility

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Objective: The study objectives were to assess 1) postoperative satisfaction and the occurrence of compensatory sweating after endoscopic thoracic sympathetic clipping in a consecutive series of patients and 2) the reversibility of adverse effects by removing the surgical clips.

Methods: Between June 1998 and March 2006, 727 patients undergoing bilateral endoscopic thoracic sympathetic clipping for hyperhidrosis or facial blushing were prospectively followed for postoperative satisfaction and subjective compensatory sweating. The effect of removing the surgical clips was assessed in 34 patients who underwent a subsequent reversal procedure after endoscopic thoracic sympathetic clipping. Satisfaction and compensatory sweating were assessed using a visual analogue scale ranging from 0 to 10, with 10 indicating the highest degree.

Results: Follow-up was complete in 666 patients (92%). The median age was 26.9 years, and 383 (53%) were men. The level of sympathetic clipping was T2 in 399 patients (55%), T2+3 in 55 patients (8%), and T3+4 in 273 patients (38%). Median follow-up was 10.4 months (range 0–83 months). Excellent satisfaction (8–10 on visual analogue scale) was seen at last follow-up in 288 (74%) of the T2 group, 33 (62%) of the T2+3 group, and 184 (85%) of the T3+4 group. Postoperative satisfaction was significantly higher in the T3+4 group when compared with the T2 or T2+3 groups ($P < .01$). Severe compensatory sweating (8–10 on the visual analogue scale) was reported in 42 (13%) of the T2 group, 11 (28%) of the T2+3 group, and 17 (8%) of the T3+4 group. Postoperative compensatory sweating was significantly lower in the T3+4 group when compared with the T2 or T2+3 groups ($P < .05$). Thirty-four patients have subsequently undergone removal of the surgical clips after endoscopic thoracic sympathetic clipping. Follow-up was complete in 31 patients. The reasons for removal included severe compensatory sweating in 32 patients, anhydrosis of the upper limb in 4 patients, lack of improvement or recurrence of hyperhidrosis in 5 patients, and other adverse symptoms in 5 patients. The reversal procedure was done after a median time of 11.0 months (range 1–57 months) after endoscopic thoracic sympathetic clipping. The initial level of clipping was T2 in 21 patients, T2+3 in 7 patients, and T3+4 in 6 patients. There was a trend toward fewer subsequent reversal procedures in the T3+4 group when compared with the T2 or T2+3 groups ($P = .06$). Fifteen patients (48%) reported a substantial decrease in their compensatory sweating (5–10 on the visual analogue scale) after reversal. Thirteen patients (42%) reported that their initial hyperhidrosis or facial blushing has remained well controlled (8–10 on the visual analogue scale) after reversal. There was no significant relationship between the original level of clipping and the interval between endoscopic thoracic sympathetic clipping and the subsequent reversal and reversibility of symptoms.

Conclusion: When compared with endoscopic thoracic sympathetic clipping at the T2 or T2+3 levels, endoscopic thoracic sympathetic clipping at the T3+4 level was associated with a higher satisfaction rate, a lower rate of severe compensatory sweating, and a trend toward fewer subsequent reversal procedures. Subjective reversibility of adverse effects after endoscopic thoracic sympathetic clipping was seen in approximately half of the patients who underwent endoscopic removal of surgical clips. Although yet to be supported by electrophysiologic studies, reversal of sympathetic clipping seems to provide acceptable results and should be considered in selected patients.

Idiopathic or primary hyperhidrosis (HH) is a chronic condition in which excessive sweating is seen in a focal pattern, usually affecting the palms, axillae, or soles. If symptoms are severe, HH can be socially and professionally disabling, and can significantly interfere with daily activities. Although HH is thought to be underreported, its prevalence has been reported as 2.8% in the United States[1] and 4.9% in China.[2] The cause of primary HH remains unknown.

When conservative measures in the treatment of HH fail, surgical treatment may be considered. First reported in 1920, sympathectomy has become an accepted method for treating HH,[3] currently performed almost exclusively using video-assisted techniques. Although thoracoscopic interruption of the sympathetic trunk is associated with a high success rate and low morbidity when used in the treatment of HH, compensatory sweating (CS) remains the most commonly

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Abbreviations and Acronyms
CS = compensatory sweating
ETS = endoscopic thoracic sympathetic clipping
HH = hyperhidrosis
VAS = visual analogue scale

reported side effect, with severe and debilitating symptoms reported in approximately 2% to 30% of patients.[4-12] Various technical modifications have been attempted to achieve the highest patient satisfaction through optimal control of HH, while avoiding the occurrence of significant CS. One such approach is the method of clamping the sympathetic nerve with surgical clips (endoscopic thoracic sympathetic clipping [ETS]), rather than cutting, coagulating, or partially removing the nerve.[13] This method has the theoretic advantage of reversibility of adverse effects of sympathectomy by simple removal of the surgical clips if postsympathectomy side effects are severe. A few authors have reported mixed results for reversal in case reports or small case series.[5,12-14] Yet, in the limited number of reported cases, the factors affecting reversibility remain largely unknown. The purpose of this study was therefore to assess the long-term satisfaction and significance of CS after ETS in a consecutive series of patients; to evaluate the effect of removal of surgical clips after ETS on satisfaction, CS, and HH; and to define factors that might adversely or positively affect the outcome of the reversal procedure.

MATERIALS AND METHODS

Between June 1998 and March 2006, all patients undergoing sympathetic nerve block, sympathectomy, or sympathetic clipping for HH or facial blushing at St Joseph's Health Center in Toronto were included in a prospective follow-up study evaluating the results of their surgery. The degree of postoperative HH or facial blushing, as well as satisfaction rate (defined as relief of original symptoms and lack of side effects) and degree of CS after sympathetic surgery, were assessed at each follow-up event using a visual analogue scale (VAS) ranging from 0 to 10, with 10 indicating the highest degree of each index (Appendix 1). The first follow-up was 1 to 4 weeks after surgery and then subsequently at 6- to 12-month intervals, through clinic visits or telephone/e-mail interviews.

Only patients undergoing bilateral ETS under our current standardized technique were included in the current analysis. All procedures were performed under general anesthesia with single-lumen endotracheal intubation. Patients were placed in a supine position with the arms abducted. Two 5-mm ports were introduced in the midaxillary line at the third and fifth intercostal spaces. We routinely used the Ternamian Endo TIP (Karl Storz, Tuttlingen, Germany) cannula for initial access into the pleural space. The pleural space was then insufflated with carbon dioxide to a pressure of less than 15 mm Hg, and the second instrument port was introduced under direct vision. The parietal pleura overlying the sympathetic nerve was incised below the rib at the desired level of clipping (ie, below the second rib for T2 clipping and below the third and fourth ribs for T3+4 clipping), and the nerve was double-clipped using the 5-mm Endoclip applier (autosuture endoscopic clips). After clip application, 5 mL of 0.25% bupivacaine solution was injected along the site of pleural dissection for postoperative analgesia. The lung was reinflated under direct vision, and all port sites were closed primarily with absorbable stitches. Postoperative chest x-ray was performed in the recovery unit, and the patient was discharged after 2 to 3 hours of monitoring in the postoperative unit.

The most recent follow-up information available at the time of analysis was used in the assessment of postoperative satisfaction and degree of CS after ETS. For patients who subsequently underwent a redo or reversal procedure, data collected immediately before the subsequent procedure were used in the analysis, as well as the most recent follow-up data after the second procedure.

To obtain procedure-specific data, all patients who underwent reversal (removal of surgical clip after ETS) were contacted via telephone or e-mail and asked to complete a separate questionnaire in which they were asked to grade their satisfaction, degree of CS, and degree of HH after their reversal procedure (Appendix 2). The effect of the reversal procedure was analyzed while comparing the anatomic level of ETS, the primary indication for ETS, the time period since ETS, and the indication for reversal.

Data were presented as mean ± standard deviation. Difference in satisfaction and degree of CS among groups was determined by the Kruskal–Wallis test, and multiple comparison post-tests were performed by the Tukey–Kramer method. Proportional difference among groups was determined using the chi-square test. All statistical analyses were performed with SAS-based software (JMP version 5, SAS Institute, Cary, NC).

RESULTS

Patients

A total of 750 patients treated surgically for primary HH or facial blushing were identified, 727 of whom were the subject of this study. Twenty-three patients were excluded from the analysis because of alternative surgical techniques, including unilateral surgery, lumbar sympathectomy, open thoracotomy, or a combination of methods.

There were 383 male patients (53%) and 344 female patients. The median age was 26.9 years (range, 14–65 years), with 106 patients aged 10 to 20 years, 329 patients aged 21 to 30 years, 209 patients aged 31 to 40 years, and 83 patients aged more than 41 years. Among the 727 eligible patients, follow-up was complete in 666 (92%). Median follow-up was 10.4 months (range, 0–83 months).

The primary indication for surgery was palmar HH in 538 patients, facial blushing or craniofacial sweating in 173 patients, and axillary HH in 16 patients (Figure 1). The anatomic level of ETS was T2 (ETS-T2) in 399 patients, T2+3 (ETS-T2+3) in 55 patients, and T3+4 (ETS-T3+4) in 273 patients (Figure 2). During the study period, our preferred surgical method has altered from the ETS-T2 level for all indications, including facial blushing, craniofacial, palmar, and axillary HH, to the ETS-T3+4 level for primarily palmar HH. This change was a result of growing evidence showing that interruption of the sympathetic trunk at the T2 level is unnecessary in the control of palmar HH and might be associated with a higher rate of severe CS.[15-19] In recent years we have discouraged patients from having T2 clipping because of unsatisfactory results and higher incidence of severe CS. During the study period, 57 patients underwent more than 1 procedure. This included 25 (3.4%) redo ETS procedures and 34 (4.7%) reversals.

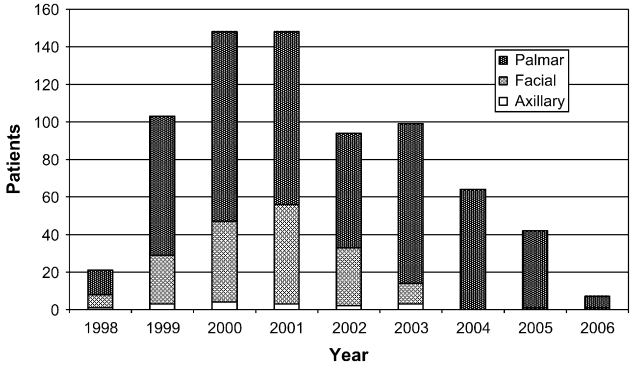

FIGURE 1. Surgical indication by year of surgery.

Postoperative Results and Adverse Outcomes

Surgical complications were rare. Chest tube insertion and drainage with subsequent hospital stay was necessary in 3 patients (0.4%) with pneumothorax and 1 patient because of take-down of excessive adhesions. One patient required conversion to a thoracotomy because of major bleeding as a result of a superior vena cava tear. She recovered well after surgical repair and experienced good control of her HH. Horner's syndrome developed in 1 patient after ETS-T2+3, and reversal was requested after 3 months. One patient returned to the emergency department with a mild fever on postoperative day 2 but did not require treatment or hospital admission.

Postoperative results after ETS are shown in Table 1. Among 666 patients with follow-up, 508 (76%) reported excellent satisfaction (8–10 on VAS). The mean satisfaction score for all patients was 8.2 ± 2. Excellent satisfaction was seen in 288 (74%) of the T2 group, 33 (62%) of the T2+3 group, and 184 (85%) of the T3+4 group. Postoperative satisfaction was significantly higher in the T3+4 group when compared with the T2 or T2+3 groups ($P < .05$).

The mean VAS score for the degree of persistent HH/facial blushing after ETS was 1.9 ± 1.8 for all patients. The mean score was 2.2 ± 1.9 for the T2 group, 1.6 ± 1.7 for the T2+3 group, and 1.5 ± 1.3 for the T3+4 groups, respectively. The degree of persistent HH/facial blushing was significantly less

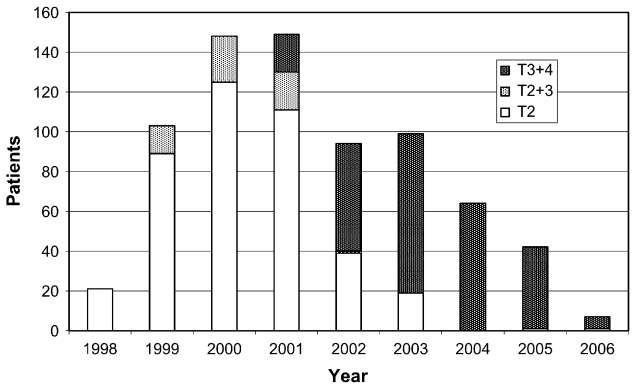

FIGURE 2. Level of sympathetic clipping by year of surgery.

TABLE 1. Postoperative results and adverse outcomes (visual analogue scale score)

Level of ETS	T2	T2+3	T3+4	
n	397	57	212	
HH/FB	2.2 ± 1.9†	1.6 ± 1.7	1.5 ± 1.3†	$P < .01$*
CS	4.3 ± 2.7†	5.3 ± 2.9‡	3.7 ± 2.5†,‡	$P < .01$*
Satisfaction	8.0 ± 2.4†	7.3 ± 3.0‡	8.8 ± 1.8†,‡	$P < .01$*

ETS, Endoscopic thoracic sympathetic clipping; *CS*, compensatory sweating; *HH*, hyperhidrosis; *FB*, facial blushing. *$P < .01$ for comparison among all groups. †$P < .05$ for comparison between groups T2 and T3+4. ‡$P < .05$ for comparison between groups T2+3 and T3+4.

in the T3+4 group when compared with the T2 group ($P < .05$), but not when compared with the T2+3 group.

Severe CS (8–10 on VAS) was reported in 49 (15%) of the T2 group, 13 (24%) of the T2+3 group, and 17 (8%) of the T3+4 group. The mean CS score was 4.3 ± 2.7 for the T2 group, 5.3 ± 2.9 for the T2+3 group, and 3.7 ± 2.5 for the T3+4 group. Postoperative CS was significantly lower in the T3+4 group when compared with the T2 or T2+3 groups ($P < .05$). The proportion of patients reporting severe CS was significantly lower in the T3+4 group when compared with the combined T2 and T2+3 group ($P < .01$).

When the primary indication for surgery was evaluated, 452 patients (96%) treated for palmar HH, 138 patients (89%) with facial blushing/sweating, and 15 patients (94%) with axillary HH reported substantial relief from their primary symptoms (0–5 on VAS) as a result of the ETS. Although 85% of patients with primary symptoms of palmar HH reported excellent satisfaction (8–10 on VAS), the rates of excellent satisfaction in patients with primary symptoms of facial blushing/sweating or axillary HH were only 62% and 53%, respectively. However, the rates of moderate or excellent postoperative satisfaction (4–10 on VAS) were 98%, 92%, and 87% for patients with palmar, facial, and axillary HH, respectively (Figure 3). Thus, the majority of patients experienced at least moderate improvement of their symptoms after the surgical procedure.

Redo Endoscopic Thoracic Sympathetic Clipping

During the study period, 25 patients (3.4%) underwent a redo ETS procedure. The level of initial ETS was T2 in 20

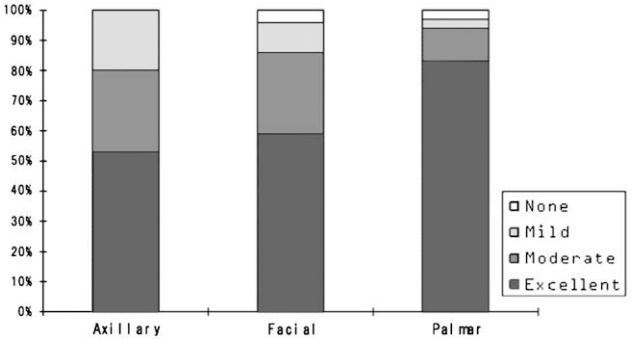

FIGURE 3. Postoperative satisfaction by surgical indication.

patients, T2+3 in 1 patient, and T3+4 in 4 patients. The reason for redo ETS was suboptimal or unilateral control of symptoms in 20 patients and recurrent symptoms in 5 patients. The median interval between ETS and redo ETS was 3.5 months for suboptimal results and 21.1 months for recurrence. Sixteen of 18 patients underwent redo ETS after ETS-T2 because of suboptimal control of palmar HH. In 7 of these cases, ETS-T3+4 was performed at the time of redo surgery. In 1 case after ETS-T3+4, ETS-T2 was added to optimize control of facial HH and blushing. Seventeen patients (74% of those with follow-up) reported excellent satisfaction after redo ETS.

Reversals

Thirty-four patients (4.7%) subsequently underwent a reversal procedure with surgical removal of the clips after ETS. The procedure was done as a day procedure with a similar setup as for the original surgery. The previously placed incisions were used for port insertion. Mild adhesions were frequently observed along the clips. However, there were no or little adhesions between the lung and the chest wall. The overlying pleura was reincised, and the clips were removed by pulling the heel of the clip with a thin-nosed grasper. The sympathetic chain was kept intact. All cases were completed as planned, and there were no major complications or conversions to thoracotomy.

Among these patients, follow-up information after reversal was complete in 31 (91%). Two patients were lost to follow-up, and 1 patient refused to participate in the study. The primary indication for reversal was severe CS in the majority (n = 32) of patients. Other adverse symptoms seen in combination were anhydrosis of the upper limbs in 4 patients, lack of improvement or recurrence of HH in 5 patients, and Horner's syndrome and sexual dysfunction in 1 patient each.

The reversal procedure was done after a median time of 11.0 months (range, 0.6–56.9 months) after ETS. Median follow-up after the reversal procedure was 34.0 months (range, 0–72.1 months). The original level of the ETS was T2 in 21 patients (5.3% of total T2), T2+3 in 8 patients (14.5% of total T2+3), and T3+4 in 5 patients (1.8% of total T3+4). There was a trend toward fewer subsequent reversal procedures in the T3+4 group when compared with the T2 and T2+3 groups ($P = .05$). Table 2 summarizes postreversal results by the level of ETS. The mean time from ETS to reversal was 16.5 ± 14.8 months in the T2 group, 21.1 ± 21.7 months in the T2+3 group, and 11.7 ± 17.6 months in the T3+4 group. This was not significantly different among the groups. The follow-up period after reversal was significantly shorter in the T3+4 group when compared with the T2 group (5.1 ± 6.1 months vs 34.0 ± 20.3 months, $P < .05$).

Fifteen patients (48%) reported a substantial decrease in their CS (5–10 on VAS) after reversal. Thirteen patients (42%) reported that their initial HH or facial blushing has remained well controlled (8–10 on VAS) after reversal. There was no difference in the change in CS or the degree of HH after reversal among the T2, T2+3, and T3+4 groups ($P = .09$ and $P = .72$ for universal comparison among all groups). Eight patients reported excellent satisfaction after reversal. Postreversal satisfaction was significantly better in the T2 group when compared with the T2+3 group (mean 5.4 ± 3.4 vs 1.3 ± 1.9, $P < .05$). By using 6 months after ETS as the cutoff time period to compare ''early'' versus ''late'' reversal, 12 patients (of 34) received their reversal procedure within 6 months from their initial ETS procedure. The proportion of patients reporting substantial decrease in their CS after reversal was 67% in the early group and 37% in the late group (P = not significant). Postreversal satisfaction was excellent in 36% of the early group and 22% of the late group. Control of HH or facial blushing was well maintained in 25% and 53% of the early and late groups, respectively (P = not significant). Overall, there was no statistical difference in the postoperative results or satisfaction between the 2 groups (Table 3).

TABLE 2. Reversal cases and postreversal results by level of endoscopic thoracic sympathetic clipping (visual analogue scale score)

Level of ETS	T2	T2+3	T3+4	
n	21	8	5	
Time to reversal (mo)	16.5 ± 14.8	21.1 ± 21.7	11.7 ± 17.6	NS
Follow-up time after reversal (mo)	34.0 ± 20.3†	30.4 ± 27.0	5.1 ± 6.1†	$P < .05$*
Change in CS	4.5 ± 3.4	1.4 ± 3.0	3.2 ± 2.9	NS
Control of HH	5.5 ± 3.9	5.3 ± 4.0	6.8 ± 4.3	NS
Satisfaction	5.4 ± 3.4‡	1.3 ± 1.9‡	2.0 ± 3.1	$P < .05$*

ETS, Endoscopic thoracic sympathetic clipping; *CS*, compensatory sweating; *HH*, hyperhidrosis; *NS*, not significant. *$P < .05$ for comparison among all groups. †$P < .05$ for comparison between groups T2 and T3+4. ‡$P < .05$ for comparison between groups T2 and T2+3.

DISCUSSION

Primary or essential HH, defined as an excessive sweating beyond that expected physiologically, affects a significant proportion of the general population. Although benign in nature, it might cause significant social, emotional, and professional disabilities. There is a potential role for genetic predisposition, given a positive family history in up to 40% of the affected individuals.[12] Social phobias are also common, mainly in combination with facial blushing and sweating,[20,21] and add substantially to patients' discomfort.

Nonsurgical treatment methods, including topical absorbing powders, anticholinergic medications, botulinum toxin injections, and various biofeedback methods, are usually helpful only for patients with mild manifestations. Thus, the majority of patients with severe forms of HH will ultimately be offered a surgical sympathectomy as a definitive treatment.

Originally used for various other indications (eg, epilepsy, glaucoma, angina pectoris, reflex sympathetic dystrophy, and Raynaud's phenomenon), sympathectomy as a treatment for HH was first reported in 1920.[3]

TABLE 3. Reversal cases and post-reversal results by time from initial endoscopic thoracic sympathetic clipping to reversal (visual analogue scale score)

Time to reversal (mo)	≤6 mo	>6 mo	
n	12	22	
Change in CS	4.5 ± 3.4	3.1 ± 3.4	NS
Control of HH	3.8 ± 3.6	5.4 ± 4.1	NS
Satisfaction	4.7 ± 3.7	3.3 ± 3.4	NS

CS, Compensatory sweating; *HH*, hyperhidrosis; *NS*, not significant.

At least 4 different open techniques were developed and widely used over the years. Those included the posterior, supraclavicular, anterior transthoracic, and axillary transthoracic approaches.[22] Although generally effective in controlling the HH, none of those techniques is simple, and the morbidity related to the open approach is substantial.

Endoscopic sympathectomy, developed over the past decade, has practically replaced the open techniques. Regardless of the method used to interrupt the sympathetic trunk, the overall results are satisfactory, the complication rate is small, and the morbidity is minimal.

There is little doubt that thoracoscopic sympathetic surgery has provided a highly reliable solution for palmar HH. This is reflected in numerous clinical reports of successful control of symptoms by surgery in more than 95% of patients.[4,8-10,12,14,16] Our results are in keeping with those previous reports, with 96% of patients undergoing ETS for palmar HH reporting substantial improvement (0–5 on VAS) of their symptoms. This high success rate was associated with excellent satisfaction (8–10 on VAS) in 85% of our patients undergoing ETS for palmar HH.

ETS was also highly successful in controlling the symptoms of facial blushing/sweating and axillary HH in our patients with success rates of 89 and 94%, respectively. However, we should emphasize that successful control of symptoms was not necessarily associated with excellent satisfaction. In our series, despite the high success rates, the rate of excellent satisfaction was merely at the 50% to 60% range for these 2 groups of patients. Therefore, for axillary HH a local approach such as excision of sweat glands might be better in controlling HH symptoms.

The optimal surgical technique and level of sympathetic trunk interruption in thoracoscopic sympathetic surgery are still under debate. Direct comparison between studies is difficult because of the subjective characteristics and lack of uniformity in reporting the measured outcomes. Nevertheless, it is possible to draw some conclusions from the existing literature regarding ETS. First, the results are similar when comparing different techniques (clipping, ablation, cauterization, and division) but for the same indication (location of HH) and at the same level of the sympathetic trunk. Thus, one should expect good results when operating on a patient with palmar HH, regardless of the technique used.

Second, sympathectomy including the T2 level is associated with a success rate of approximately 90% to 100% in the treatment of craniofacial HH and facial blushing. However, it has been repeatedly reported that sympathectomy including the T2 level is associated with significantly worse CS and a lower degree of satisfaction postoperatively[5,8,16,17,18] when compared with sympathectomy not including T2. Similarly in our series, ETS-T2 and ETS-T2+3 were both associated with a higher rate of severe CS and significantly lower postoperative satisfaction when compared with ETS-T3+4. There was also a trend toward more reversal procedures in the combined T2 and T2+3 groups when compared with the T3+4 group.

CS is the most significant adverse effect after sympathectomy. Approximately 10% of our patients sustained severe CS, more than the 6% reported by Reisfeld and colleagues[12] in their large cohort (1312) of patients, but less than reported by other groups, who described up to 30% of patients with severe CS symptoms.[7,9,18] The common hypothesis for CS is that this phenomenon is a thermoregulatory mechanism by which the sweat glands attempt to compensate for the decreased amount of secretory tissue. Several authors have therefore suggested that reducing the extent of sympathetic nerve interruption will result in reducing the occurrence of CS.[17] Currently, however, there are no electrophysiologic studies to support these concepts. In addition, it has been suggested that the anatomic variations in the sympathetic trunk, including aberrant pathways between the upper thoracic and the intercostal nerves, enable fibers to bypass the sympathetic chain and might be one of the main reasons for failure of surgical sympathectomy.[23] As a result, some surgeons are routinely dividing or coagulating all the aberrant fibers around the level of the sympathectomized chain. Yet, there are no studies to support this hypothesis, and no clinical data are available to support the routine use of this maneuver during ETS. In our experience, only 3.4% of the patients required redo surgery because of failure of the original procedure, and most of them simply required the addition of T3T4 clipping to a preexisting T2.

The main limitation in evaluating the results of surgical sympathectomy is the inability to objectively measure the outcome. Although most patients are satisfied with the results, all the methods for outcome measurement are of a subjective nature. Many centers have developed different scales/parameters to evaluate success rate after sympathectomy ETS, none of which is widely used by others. Only a few groups are routinely monitoring physiologic parameters, such as heart rate and skin temperature, during or after the surgical procedure.[25] However, these parameters might not be precise or long-lasting.

Yet, in a procedure focused primarily on achieving high patient satisfaction, the main outcome is, indeed, the patient's subjective evaluation of his or her symptoms. Thus, it seemed reasonable to assess our patients using the VAS,

which is easy to use and allows for a relatively simple and accurate self-assessment by patients.

The concept of potential reversibility of adverse effects after CS by clip removal is attractive and intuitively sound. After sympathectomy using nerve cutting or various other methods of nerve injury, the only reliable way to restore trunk continuity is by using a nerve graft to interpose between the cut/injured ends.[24] This is a complex surgery that requires harvesting and anastomosis of nerves. However, if restoration of continuity in the sympathetic chain by removal of clips that initially crushed the chain will allow for renewal of conductivity in the trunk, then the method of sympathetic clipping (in which the continuity of the sympathetic trunk is maintained) is clearly preferable as the initial surgical treatment for HH, because it maintains the option of effective and relatively simple reversibility. Before the current study, there were only a few reports assessing reversal of sympathetic clipping,[5,12-14,16] most of which are case reports or small case series. Our group of 34 patients with reversal is the largest reported series to date. We are also the only group to follow their reversal patients prospectively for a relatively long period of time (up to 5 years). Although we realize that the T3T4 reversal group was followed for relatively short period (median of 5.1 months), simply reflecting the fact that we started performing T3T4 almost exclusively during the last 3 years, the follow-up for the other reversal groups was significantly longer. Thus, the substantial decrease in CS in approximately half of the patients after reversal is reliable, and the results were maintained in some patients for several years. We do not have a good explanation for the fact that approximately 40% of patients did not experience recurrence of their original sweating/blushing pattern after the reversal, especially because some did show reversal of their CS. It is unclear why a patient may experience reduction of CS after reversal while not experiencing recurrence of his/her original symptoms. Currently, there is no valid or reproductive animal model to clarify the actual mechanism of HH and to validate the concept of sympathectomy and reversal. The only reported in vivo animal model to evaluate the activity of the sympathetic chain within this concept was reported by Lavian and colleagues,[26] who developed an electrode device that was implanted on the stellate ganglia of dogs to allow for a chronic animal model with continuous recording of neuroelectrical signals. They demonstrated long-term reproductive signal recording by the device but have not repeated it in the setup of a sympathectomy model. Thus, more research is clearly needed to support the concept of sympathectomy, and in particular that of reversibility.

CONCLUSIONS

What are the clinical implications of our study? First, the study provides additional evidence to support previous reports showing an excellent safety profile and long-term outcome for sympathectomy. Second, the study provides some evidence for the usefulness of reversibility. It seems that reversal might help a substantial proportion of patients with severe adverse effects after sympathectomy, and that the results of the reversal procedure are long-lasting. Third, the fact that approximately half of the patients undergoing reversal in our experience reported a substantial decrease in their CS, but that approximately one third did not experience a recurrence of their original HH even after clip removal, cannot be simply explained by nerve regeneration after clip removal. Thus, some exciting questions are raised with regard to possible alternative mechanisms and the need for better understanding of the activity of the sympathetic chain, as well as its relationship to HH.

GTS

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GTS

Discussion

Dr James Allan (*Boston, Mass*). Thanks very much. That was very nicely presented and I want to congratulate you on adding a large body of data to the literature.

I find the data provocative in several respects. First, in your series, 25 patients (3.4%) underwent repeat surgery due to a lack of effectiveness of the initial operation. The majority of these patients had initially been clipped at just the T2 level for palmar hyperhidrosis. In my personal experience of about 60 patients, I have never needed to reoperate on a patient; however, I perform a T2 to T4 ablation with division of accessory nerves, not just a T2 clipping. So I would like to know whether the initial failure in these patients reflects (1) that clipping at a given level may be inferior in efficacy to cutting or ablating at the same level, (2) that some patients simply require longer sympathectomies than others in an unpredictable fashion, or (3) that the initial failures are a reflection of performing a procedure that does not address accessory sympathetic fibers?

Dr Sugimura. Dr Allan, thank you very much for your comments and questions.

It is true that we had 25 redo surgeries that required redo because of suboptimal results or what looked like early recurrence of their symptoms, and the majority were in patients that received T2 clipping for palmar hyperhidrosis.

In regards to the difference between the clipping method and the cutting or ablation method, I think that our results using the clipping method are comparative to the results utilizing other methods in terms of satisfaction or treatment success. Some authors with experience with both methods even suggest that clipping was more effective. I do not think that the redos were a result of inferiority of the clipping method. I personally think that accessory sympathetic conduction might have been responsible, or at least in part, for suboptimal results or early recurrences resulting in redo. We do not routinely clip aberrant nerve fibers, and the fact that you see more aberrant fibers at the T1/T2 levels, as compared to the T3/T4 levels is the reason for my suspicion. Therefore when we perform redo sympathetic clipping, if we find an aberrant fiber at that time, we ablate that nerve. After experience with clipping at both T2 and T3/T4 levels, we now strongly believe that T3/T4 clipping is a far more superior method to T2 clipping that does not require further intervention to the accessory nerves. Because most of the redos were done following T2 clipping, in fact we have added clips to the T3/T4 levels in most of the cases at the time of redo.

Dr Allan. My second question for you relates to the 2 patients (among the 34 patients who underwent reversal) that did so for reasons other than compensatory hyperhidrosis. I believe from your manuscript, one of them may have had a Horner's syndrome and the other may have had sexual dysfunction, which is a complication that I was not aware of. Can you describe these 2 patients, if I've understood the presentation correctly, and what their outcome was after reversal?

Dr. Sugimura. The patient who presented with Horner's-like symptoms was a T2 clipping case done in the early era. It wasn't the typical presentation of symptoms, but there was a mild degree of ptosis and some bloodshot conjunctiva, which was among multiple complaints including significant compensatory sweating. We did perform reversal in that case.

Dr Allan. Was there symptomatic improvement in that patient after reversal?

Dr Sugimura. There was mild symptomatic relief in that patient. The patient presenting with sexual dysfunction also had an L2 to 4 chemical block of the sympathetic chain for plantar hyperhidrosis close to the time of thoracic sympathetic clipping.

Dr Allan. Finally, among the 32 patients who underwent reversal for compensatory hyperhidrosis, did you notice a correlation between the resolution of the compensatory hyperhidrosis and the subsequent recurrence of the primary symptom?

Dr Sugimura. As we showed in the presentation, there was a trend toward association between the two changes in the symptoms, meaning if you do an early reversal, you'll have more patients reporting significant relief from their compensatory sweating and at the same time less patients who can maintain their level of control of hyperhidrosis.

Dr Allan. Thank you

Dr Dan Meyer (*Dallas, Tex*). That was an excellent presentation.

I have three quick questions. Do you do any intraoperative monitoring, such as palmar temperature monitoring, to make sure that you have interrupted the blood supply during your sympathectomy?

Dr Sugimura. No, we do not.

Dr Meyer. Are there a group of patients that you've found that you've predicted preoperative factors that may predict severe compensatory sweating that you would not offer a sympathectomy to? Because there are patients who have diffuse sweating, worse in the hands or axillae, that you worry that they may get severe compensatory sweating postoperatively.

Dr Sugimura. I think it's more about the indication for clipping. If you are to treat a patient with a primary complaint of craniofacial hyperhidrosis, then we believe that it's more effective to perform a T2 clipping. However, we know that T2 clipping is associated with worse compensatory sweating. So if you call that a high-risk group for significant compensatory sweating, then that might be the case.

Dr Meyer. And the last question, have you considered just doing a T3 sympathectomy instead of the T3/T4 clipping? What do you think the gain of the addition of the T4 is?

Dr Sugimura. First of all, we don't have experience with single-level clipping. We are aware of reports showing excellent results and literally zero compensatory sweating with the single level sympathectomy at the lower level of the sympathetic trunk, and I agree that that is a method that we should look into in the future. I believe that a lot of people who are experienced in this surgery think that

the less manipulation you do to the sympathetic trunk, the less adverse effects you create, and if you can achieve the same results with less manipulation, I think that is the optimal way to treat.

Dr Douglas Wood (*Seattle, Wash*). I want to follow up on Dr Allan's last question, which I guess I'm not sure we answered adequately. I think that he is asking whether in individual patients was there a correlation in time of when the sympathectomy was reversed and the recurrence of hyperhidrosis and relief of compensatory sweating? In individual patients was the relief of compensatory sweating accompanied by a recurrence of symptoms?

Dr Sugimura. It usually was. But there was a small number of patients who experienced relief from their compensatory sweating after reversal while enjoying persistent control of hyperhidrosis, and those patients were more in the T2 group—well, we had more reversals in the T2 group to start with. My personal feeling is that with all the measures that we use to look at the outcomes being so subjective, we have to be very careful in our attempt to quantify the relationship between these 2 outcomes. In some people with a huge burden of compensatory sweating, with even mild relief after reversal they might feel quite satisfied, regardless of the change in their state of hyperhidrosis. It's hard to really understand the quantitative association unless we do some confirmation with electrophysiological studies.

Dr Allan. I agree that patient selection is a key component to subsequent patient satisfaction. I would not want to bring 10% of my patients back to the operating room due to a failure to control the primary condition, or due to my creating a side effect that turns out to be worse than the primary condition. Therefore, I make a strong effort to be certain that the patient is significantly bothered by palmar hyperhidrosis. I do not typically offer surgery for isolated craniofacial hyperhidrosis, and also try to limit operating on isolated axillary symptoms, as the reported efficacy of sympathectomy for axillary symptoms is only about 70%.

Dr Sugimura. Thank you very much. I couldn't agree more with that comment. We are being more and more selective in our patient selection. There are about 10% of patients who come to see us with complaints of solely craniofacial hyperhidrosis or axillary hyperhidrosis. Because we now know that sympathetic surgery in this population is more likely to fail or cause significant adverse effects, we basically discourage these patients from surgery.

GTS

Appendix 1. Endoscopic thoracic sympathetic clipping follow-up questionnaire

1. How would you rate your current degree of facial / hand / armpit / foot sweating, or facial blushing?

None *Debilitating*

0 1 2 3 4 5 6 7 8 9 10

2. How would you rate your current degree of compensatory / reflex sweating?

None *Debilitating*

0 1 2 3 4 5 6 7 8 9 10

3. What is your current degree of satisfaction with the surgery (ETS)?

Not satisfied at all *Completely satisfied*

0 1 2 3 4 5 6 7 8 9 10

1. Location of compensatory sweating: (Mark all that apply)
   - Face
   - Chest
   - Abdomen
   - Feet
   - Neck
   - Back
   - Buttocks/thighs
   - Gustatory
   - None

2. Other adverse effects after sympathetic clipping:

_____

_____

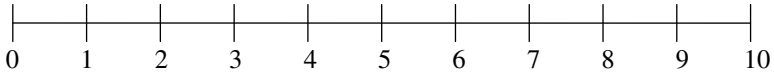
Appendix 2. Endoscopic thoracic sympathetic clipping follow-up questionnaire (after reversal)

1. How would you rate your current degree of facial / hand / armpit / foot sweating, or facial blushing?

Same as before ETS *Complete dryness*

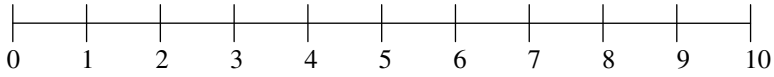
2. How would you rate your current degree of compensatory / reflex sweating?

Same as before reversal *Back to normal (before ETS)*



3. What is your current degree of satisfaction after reversal?

Not satisfied at all *Completely satisfied*



Other effects following removal of sympathetic clips:

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